his initial experiments, tracings, and analyses have been conducted, lead us to hope that we have at least got an instrument which will enable us to solve the elementary problems of phonetics that have hitherto almost baffled us, although it is not suited, as yet, to fix those delicacies of utterance which were my own special object of investigation.

April 30 ALEXANDER J. ELLIS

ON repeating the experiments with the phonograph narrated by Mr. A. J. Ellis in NATURE, vol. xvii. p. 485, upon a different instrument, I have found the results of my experience to differ in several respects from his. Doubtless each instrument possesses its own individual characteristics; hence it will be the more needful to exercise caution with respect to generalisation, especially as the existing instruments are few and in the hands of few observers. Mr. Ellis has been careful to state the nature of the instrument with which his results were obtained, and the name of Mr. Stroh is a guarantee for the construction of the mechanism. The instrument with which I have been working is of homelier make, and not provided with a driving-train or governor, but simply turned by hand. The same disc—a three-inch ferrotype plate—serves as receiver and transmitter of the voice. The foil used has been, if anything, a little too thin for the purpose.

On trying the sounds *aabaa*, *aadaa*, &c., I found the consonants clearly distinguishable, except the sibilants. *Aajaa*, which is stated by Mr. Ellis to be faultily delivered by the instrument, was perfectly recognisable, and could be distinguished from *aadaa*. Neither was there any confusion between *jack* and *dack* or *tack*; but *jacques*, with the soft *j*, was sounded out by the instrument as *hāāk*. My phonograph makes the clearest possible difference between the words *bout* and *bite* when carefully spoken, the diphthongal sounds coming out beautifully as *bāāōōt* and *bāāēēt*. On reversing the motion of the handle, *tēēāāb* and *tōōāāb* were unmistakable. The double nature of some of our consonantal letters is very clearly demonstrated by this process of reversal of motion, as Messrs. Fleeming Jenkin and Ewing have already shown. To the sounds they name let me add that of *ch* in the word *cheque*, which we ordinarily pronounce *tshek*. This word gives a very peculiar sound when reversed in the machine.

The greatest difficulty—that of getting an instrument to acknowledge the sibilants—is a difficulty that all who have worked with phonograph, phonautograph, or telephone, admit. The remedy mentioned by Prof. Mayer, that of using a mouthpiece with a very small hole, has the inconvenience of diminishing materially the loudness of the articulation of the machine. I have found it better to fasten a strip of card or watchspring across the opening, edgeways, so that the voice impinges on the edge of the strip. With this device sibilants are improved; the word *scissors* becomes practicable, though "*Scots*" is still intractable. One of Mr. Stroh's instruments, which was shown at the Crystal Palace during Easter week, gave *s* and *z* fairly. In a familiar phrase the *s*es are not much missed: *Steady, boys, steady*, is given with less marked defect of speech than if uttered as *thteady, boyth, thteady*. Another point of interest that has not, I think, been yet mentioned by observers is, that the marks corresponding to the vowel sounds differ when the mouth is at different distances from the vibrating plate, but that yet there is no difference in the vowel subsequently emitted by the machine; a result which confirms the previously known independence of the vowel sound of the phase of its component partials. For some time I thought my phonograph guilty of dropping its *h*'s (though not made within the sound of Bow bells), but when that letter is spoken rapidly in a word it is recorded faithfully. *Happy land* is well heard in the instrument; and *How do you do?* is also aspirated. Curiously enough, this sentence is spoken almost as well backwards as forwards (except the aspirate), especially if spoken to the machine with a strong Scottish accent. It is remarkable how useless an instrument without a clockwork regulator is for reproducing even the simplest airs: they are simply lost in noise. Altogether the study of speech by the phonograph is most interesting, and will furnish some most valuable data to students of language and of acoustics. It is impossible to witness its performance without a tribute of acknowledgment to the extreme ingenuity and skill of its inventor, Mr. Edison.

SILVANUS P. THOMPSON

University College, Bristol, May 1

On the Use of the Virial in Thermodynamics

THE ingenious experiment and the deductions from it, described by Mr. S. Tolver Preston in NATURE, vol. xvii. p. 31, throw a flood of light on the subject of availability of heat-energy, which altogether alters the basis upon which the hitherto imperfectly expressed conditions of the use of this form of energy will be made to rest. Mr. Tolver Preston has, in fact, discovered that discriminating "sprite," or being whom Prof. Clerk-Maxwell imagined ("Theory of Heat," 1875, p. 328) singling out the fast-moving, and separating them in a space by themselves (without any expenditure of energy), from the slow-moving molecules of a gaseous mass; or what is nearly equivalent to this, he has at least shown how *some* fast-moving and *some* slow-moving particles of a mass of gas originally in equilibrium, both as to temperature and pressure, *will naturally* be so guided amongst each other, that their joint energy will become more available than it was before. But it has, perhaps, not occurred to Mr. Tolver Preston and to some of your readers, that this power or faculty of rendering heat-energy available, which mutual diffusion of heterogeneous gas-masses, either through a porous septum or in their own contiguous layers possesses, is a consequence of the general form of efficacy belonging to force, of which Prof. Clausius pointed out the existence in his important propositions on the "virial,"[1] as he has termed one of the two members, of which this kind of mechanical tendency of force is the sum. The other member of a force's "*radiality*" (as it may be termed), "with respect to a given point," is the *vis viva*[2] of the material particle upon which it acts, in a space of which the selected point is the origin. In description of this newly-discovered natural tendency of a force with respect to a given point or focus, it is enough to say that while the statical *moment* of a force, or the product of the distance of its point of application from a point or fulcrum by the resolved part of the force perpendicular to this distance tends to increase uniformly the *moment of momentum* (defined similarly with that of *force*) of the particle upon which it acts, so does the "radiancy" of a force, or the product of the distance of its point of application from a given point or "focus," *together with the vis viva* of the particle upon which it acts, tend to increase the "radiancy of momentum" of the particle described in the same way as the radiancy (or the first term of the radiality) of the force, as just defined. We may speak of the radiancies of equal and opposite reactions, or of force-pairs, in the same way that we deal in statics with the moments of couples; with similar general properties of their equilibrium, including the resolution of the total radiancy (like the impulse, the horse-power, and the moment) of a system of forces, into an internal and an external part with respect to the centre of mass of a material system upon which it acts; and there are principles of conservation of moment and of radiancy of momentum about any point, taken as centre, of all the force-pairs whose moments and radiancies balance each other on a material system. Only the system's *vis viva* referred to the centre is in the latter case the rate of change of its radiancy of momentum relatively to it. It is in the same way that the conservation of the motion of the centre of mass, and the conservation of energy, are principles of nullity or of inaction of two other forms of force-agency balancing each other on a material system (the impulse of forces, and the product of their impulse by the virtual velocity of their point of application, or their "horse-power") to which we are obliged to have special recourse to resolve the particular varieties of questions of the "transfer of energy" which occur in mechanics. But it is remarkable that the radiality of a force-pair includes the *vis viva* of its mass-couplet as one member of its mechanical efficacy, and a surprising example of an agent (evidently the agent of heat-distribution) here presents itself in which *vis viva* itself is one of the active elements of the mechanical variation or compulsion! Its total tendency in any body acted on internally only by directly reacting force-pairs is the total *vis viva*, and the sum of the virials of those force-pairs, diminished, if the body is subjected externally to a uniform pressure normal to its surface, by three times the well-known product of this latter pressure by the volume of the body (written $-3\,pv$).

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[1] *Poggendorff's Annalen*, vol. cxli. (1870), p. 124. But Clausius, it should be remarked, gives the name "virial" *to half* of the quantity which I have described below as the "radiancy" of a force. An exposition of Clausius' new mechanical expression, the virial, with an explanation by its means of the process of condensation of vapours into the liquid state, was given by Prof. Clerk Maxwell in his lecture to the Chemical Society on the molecular theory of the constitution of gaseous and other bodies, in 1875. (See NATURE, vol. xi. p. 357.)

[2] Using this word for *twice* the quantity usually described as a particle's "kinetic energy."

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In the mutual inter-diffusion without change of temperature of two gases of different densities through a fixed porous diaphragm, although no energy is withdrawn from or communicated to either of the gases, the rate at which single molecules take their equal measures of gas volume through the partition being very different, like their velocities, the measure of gas-volume which accumulates on the side of the denser gas soon raises the pressure there, increasing the intensity of the mechanical tendency $3\,pv$ on that side of the partition, while the same kind of mechanical tension diminishes on the other, and the temperature on each side of the partition is at the same time unaffected. As the porous diaphragm by its immobility (which prevents one of the sets of molecules from doing any work upon the other) resists the resulting force upon it, its counter-tendency is entirely derived from the increase of its own external virial, which has sprung up (at no expense of work, supposing the diaphragm to be perfectly rigid) in maintaining everywhere in spite of their impacts the common temperature or mean energy of both sets of molecules. Were the diaphragm away, it is evident that the rapid flow of rare gas-volume across the confines between the two gases towards the denser side would cause the centre of mass of the gas-layer, in which the mixture begins, to move bodily away from the denser gas, just as the diaphragm would do if it were free to move; and the *bodily motion* so given to the medial gas-layer will, as a form of external radiality in the layer, arising from the heterogeneity, require, in order to be constantly neutralised in the whole body of the mixing gases, such a redistribution of their temperature and density to be taking place at every instant throughout the two bodies of gas placed in communication, that their centre of mass as a connected (but otherwise *isolated*) system may never undergo any change of place during the mutual diffusion. The space originally occupied by the rarer gas will accordingly become the hotter, and that by the denser the colder portion of the whole volume which the gases continue to occupy when they are mixed.

It is in the same way that we can explain the action of regenerators in such air-engines as Stirling's and Ericson's, in passing through which gases change their temperature and volume (and therefore their tendency or "radiality," $E - 3\,pv$), at constant pressure, the counter-tendency being at the same time lodged or relaxed during the process in the regenerator, where it must be kept by non-conduction in the *tense* state (of actual heat-energy and virial combined) of "radiality" corresponding to the similar "heat-tension" of the gas by which its heat-energy exchanges are secured. The property of the usual non-conductivity required in the regenerator, is one of indifference of the molecules of a substance to the radiality (or to the sum of the sensible heat and the virial), of neighbouring molecules, or in which different values of the quantity $E - 3\,pv$ of small neighbouring parts of the substance equalise themselves with difficulty through the mass. But perhaps it is not the inter- but only the *intro*-molecular forces that furnish the radiality (and "virial") that determines the transmission of heat? If the former forces balance each other, which they do when the body is not vibrating by its elasticity, the virial of the intro-molecular forces only, together with the *vis vivæ*, may be "conservative" with regard to heat-energy, and may be employed in its transmission? Since radiancy of momentum is not heat-energy, we see that this natural effect of force radiality, or of virial and *vis viva* combined, can only be converted finally into actual heat-energy by some mechanism peculiar to the molecular structure of the solid and liquid bodies in which the heat-energy transmission takes place. Some kind of heat-engine apparently effects this process, for example, at the confines between the vapour and the liquid, when steam is condensed into water, but it is certainly a non-reversible one when the water-spray is colder than the steam which it condenses; and in the conduction of heat by solid bodies the process is also a non-reversible one; we only know the part which sensible heat, as temperature, or *vis viva*, acts in promoting heat conduction; and the virial by which it is perhaps also carried on, and which with *vis viva* conserves radiancy of momentum, may also be a fellow-regulator of the operation of which we have no certain knowledge, and over which we certainly have no direct control. But that it should invariably tend to lower the availability of heat, by heat conduction among the comparatively fixed molecules of liquid and solid bodies, will not, perhaps, when the internal motions of molecules are better understood, be more difficult to demonstrate from some theory of its action, than that it should sometimes serve to raise the availability of thermal energy by its action on heterogeneous gas masses. A. S. HERSCHEL

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P.S. — Maturer reflection, since the first impression of surprise which Mr. S. Tolver Preston's announcement of the new experiment to which it relates caused me to express at some length, and perhaps unguardedly, in this letter has shown me that the properties of the virial, easily as they may conduct to some important results, do not, in this case, supply a complete solution of the problem of the final state of two gas masses at the same pressure but of two dissimilar densities on temperatures left to diffuse into each other in a confined space. The equal pressure on all parts of the inclosure predetermines the fixity of the centre of mass during the process, and consequently an unequal distribution of density, and therefore of temperature finally, when the mixture is complete; but the equation of the virial or the principle of conservation of the radiancy of momentum supplies no certain information what must be the law of this final distribution, one of its terms, $3\,pv$, or the virial of the inclosing pressure, being capable of undergoing unknown variations during the progress of the diffusion; and although the stationary condition of the mass at last implies that this term will not be permanently changed, yet both its value and that of the system's total moment of inertia round its centre of gravity (the *acceleration* of whose magnitude is the rate of change of the radiancy of momentum) may vary in the interval, with the result of leaving the latter moment of inertia permanently altered to an extent and in a way which cannot be defined. When in the simple case of a perfect gas the condition of the virial fails to afford positive information regarding the law of conduction and transference, or of rest and repose of heat in them under various distributions of temperature, it can hardly be expected that the same principle will furnish useful and definite results regarding heat-transmission through solids and other kinds of bodies of which the modes of molecular aggregation are almost totally unknown. A. S. H.

Time and Longitude

THERE is an old and instructive problem which I have lately propounded to several people, and have been struck by the great variety of answers given to it.

Although we often lose sight of the fact, it is nevertheless true that any given day or year does not begin all over the world at the same moment, but, commencing first at some point in the east, it travels round westward with the sun, so that two different years are often coexistent at the same moment, and it is easily possible for two events to occur a few hours apart, and yet that which happened first to occur in 1878, and the later event in 1877. In the same way each day of the week starts somewhere to the eastward of us and dies somewhere in the west. Taking, then, any given day of the week as Monday, the problem is—When and where did last Monday first commence, where did it end, and how long did it exist? Or, to put a similar question, Where did the year 1878 first commence, and at what Greenwich time?

I will simply state my belief that last Monday commenced in New Zealand somewhere about noon on Sunday, but not at noon, its commencement at that time and place being in no way connected with its position as our antipodes, but being a mere accident of civilisation. If the whole northern hemisphere should become civilised and inhabited, the day would then almost certainly commence at Behring's Straits, and would last forty-eight hours. A person crossing Behring's Straits east or west would gain or lose a whole day just as he now does by sailing round the globe; so that he might easily cross over and spend a few hours of to-morrow with his friends and return in time for dinner, or might enjoy the New Year's Eve on two successive days.

If the Pacific Ocean became inhabited land, a meridian would have to be chosen as a starting point for the day, and a person stepping across this imaginary line would gain or lose a day. At the same moment that Sunday morning was commencing on the one side of this line, Monday morning would be commencing on the other, and there would be constantly two different days going on side by side with twenty-four hours' difference of time between them, though only a few yards apart. It would be possible for a person standing astride this line to have for an instant one foot in Monday morning, the other foot in Monday night, and his body in the previous Sunday.

I purposely avoid giving any reasons, and do not assert that all my views are correct, but I throw out the problem as an amusing one for argument and discussion, as it abounds in

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